Imaging the Earth from Space: Applications in Geology and Geophysics

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There are 3 main regions of the electromagnetic spectrum, controlled by "windows" in the Earth's atmosphere and commonly used for remote sensing: Visible-Near Infrared (VNIR), Thermal Infrared (TIR), and microwave. Each region allows complementary information about the Earth to be derived and each requires a different technology to acquire the data.

Visible-Near Infrared images are typically acquired by CCD arrays and capture either multispectral images in a half-dozen or so relatively broad channels, or hyperspectral data in hundreds of narrow-band channels. A third common technology opts for high spatial resolution at the cost of spectral coverage and obtains 10 m or better resolution in a single very broad panchromatic band. Current examples of VNIR multispectral imagers are the Landsat Thematic Mapper, part of a series of satellites flown since 1972; the French SPOT satellite; the Moderate Resolution Imaging Spectroradiometer (MODIS); and the VNIR bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The last two instruments were recently launched on the EOS Terra satellite. Recent launches of high spatial resolution satellites include the IKONOS 2-m imager as well as the older SPOT panchromatic band. Other satellites are planned for this niche.

The information contained in the VNIR region of geologic interest is mainly composition, as inferred by absorption features in the spectra of minerals. These absorption features indicate the presence and type of iron-bearing minerals, clay minerals, and other common rock-forming minerals and rock coatings. Recent advances in instrument calibration, removal of atmospheric effects, and statistical deconvolution of spectra have allowed mineral abundance maps to be constructed from hyperspectral and multispectral data sets.

Thermal Infrared images also depict composition, but are most sensitive to the bulk silica content of rocks. Once again, improvements in atmospheric removal and instrument calibration have allowed quantitative compositional information to be gathered in the TIR. The atmospheric window used is typically at a longer wavelength than is useful for detection of hot objects. A shorter wavelength window is sometimes used for fire fighting. Typical instruments used for TIR remote sensing consist of sensitive thermal detectors in arrays that capture the Earth's emitted radiation. The first multispectral TIR instrument to be flown in space is part of ASTER. Up until that instrument was launched, only single-channel broad-band TIR sensors were flown as part of the Landsat series. Aircraft instruments have also produced a large collection of multispectral TIR images.

The most common imaging instrument in the microwave region of the spectrum is RADAR. A number of imaging radars have flown in space, most notably the single-channel Seasat, SIR-A, SIR-B, ERS-1 and 2, JERS-1, and Radarsat and the multispectral, multipolarization SIR-C. Unique to radar is the fact that it actively produces its own illumination, allowing day/night collection. Radar produces information about the physical nature of the Earth's surface. It is most sensitive to roughness of the surface near the radar wavelength (typically cm to m) and to the moisture content of soil. In very dry sand, longer wavelengths have been shown to penetrate several meters and produce images of the subsurface. The recent development of imaging radar interferometry is currently being used to map topography and topographic change. The Shuttle Radar Topography Mission collected data for a digital topographic map of nearly the entire globe at 30 m resolution. Free-flying satellites are currently mapping surface deformation caused by earthquakes, volcanoes, and ground subsidence with a few mm precision in the vertical.

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